THE SMOKE NUISANCE

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Reprinted from the Fourth Annual Report of the
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INTRODUCTION

NEITHER for those who live in, nor for those who ever visit an industrial centre where large quantities of bituminous coal are burned, is a definition of the smoke nuisance necessary. Its effects are apparent on every side in such cities and no man, woman or child escapes them. The smoke nuisance is truly a modern plague.

It is, however, only within the last few years that any serious study has been given to the various phases of the problem, with the possible exception of the engineering phase. A remarkable change, however, has taken place. There is not a city in the country that has the smoke nuisance in an acute form, that is not aroused to the seriousness of the problem and that is not attempting in one way or another to abate it.

Investigation in Pittsburgh

It is rather appropriate that the city of Pittsburgh, with its sobriquet 'The Smoky City,' should be held up as illustrating most forcibly the evils of the smoke nuisance, and that it should be the centre of an investigation which claims for itself comprehensiveness of plan, if no other merit. It leaves no phase of the smoke problem untouched. The donor of the fund for this investigation was actuated by the belief that a thorough investigation would reveal not only the nature, extent, and precise cause of the smoke nuisance, but also the remedies that would make its abolition possible and practicable. To carry out this investigation, he placed $40,000 in the hands of Professor Robert Kennedy Duncan, Director of the Department of Industrial Research of the University of Pittsburgh.

In this paper we will endeavour to present the various phases of the problem as they have come to our notice in our work in the smoke investigation.

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* For a comprehensive scientific treatment of this subject the reader is referred to *Smoke, A Study of Town Air*, by Julius B. Cohen and Arthur G. Ruston, both of the University of Leeds; London, Edward Arnold, 1912.

Chemical Analysis of Soot.

When one considers the very different conditions under which coal is burnt, it is obvious that the character of soot must vary. All conditions in the furnace greatly affect the amount of carbon lost as soot, but the fact stands out, that, where equal amounts of coal are consumed, domestic installations are worse offenders than boiler furnaces. Loss of efficiency through the escape of soot itself is small. This is, however, an indication of a far greater loss in the shape of unburned, invisible gases, which loss may reach as high as 10 per cent.

Soot is composed of:

(1). *Carbon,* in a finely divided state. This, as is well known, is lamp black, the basis of most black paints, and it has a great covering power. It has the power of absorbing the corrosive acids which are produced by the combustion of coal containing sulphur.

(2). *Tar.* It is common coal tar which makes the soot cling tenaciously to everything with which it comes in contact. Tar contains carbolic acid and other creosote bodies of an injurious nature.

(3). *Acids.* Sulphurous acid, (H_2SO_3); sulphuric acid, (oil of vitriol, H_2SO_4); sulphuretted hydrogen, (H_2S); hydrochloric acid, (HCl).

These acids corrode and tarnish all the common metals. They attack many of the stones and building materials, especially limestone. Draperies, paper, paints and other decorative materials suffer to no less extent. In burning the sulphur in the coal, the relatively inactive sulphurous acid is produced, but this soon becomes oxidized in the air to the far more active and corrosive sulphuric acid. These acids are also poisonous and detrimental to health.

(4). *Ash.* This is the least injurious of all the constituents of coal and may be, for all practical purposes, considered as common dirt.

(5) *Ammonia,* (NH_3). Ammonia is found in soot only in very small quantities and is of less importance than the other corrosive agents.

(6). *Arsenic.* This poisonous substance has been found in small quantities (generally less than 0.1 per cent. of the soot).

The amounts of these constitutnets of black smoke vary between the widest possible limits, depending upon the composition of the coal, methods of firing, amount of air, temperature of the furnace, and other conditions. The following analysis of soot taken from Cohen and Ruston's *Smoke, A Study of Town Air,* gives a good general idea of what one must expect:

PITTSBURGH'S PALL OF SMOKE.

SOOT FROM BOILER FURNACE

Constituents of Coal		Base of Chimney	13 feet from Base	70 feet from Base	Top of 110 ft. Chimney
Carbon	69.30	19.24	16.66	21.80	27.00
Hydrogen	4.89	2.71	0.86	1.44	1.68
Tar	1.64	0.09	0.28	0.80	1.14
Ash	8.48	73.37	75.04	66.04	61.80

DOMESTIC SOOT

Constituents of Coal		Kitchen Flue	Dining Room Flue	
			Bottom, 5 ft. from grate	Top, 35 ft. from grate
Carbon.....	76.80	52.34	36.45	37.22
Hydrogen . ..	4.90	3.68	3.51	3.51
Tar	0.88	12.46	34.87	40.38
Ash	1.80	17.80	5.09	4.94

PER CENT OF FREE ACID IN SOOT

Sources of Sample	Base of Chimney	Top of Chimney
Brass foundry	0.00	0.65
Study flue	0.50	....
Kitchen flue	0.00	....
Boiler chimney	1.62	0.56
Fire-place	0.37	0.00

Dr. Russell found that the rain-water did not contain acid unless it also contained soot. The amount of free acid, calculated as sulphuric acid, in nine samples was found to be: 1.4 per cent.; 0.5 per cent ; 7.2 per cent ; 0.0 per cent ; 4.9 per cent ; 0.8 per cent ; 1.2 per cent ; 2.3 per cent ; 0.0 per cent.

From the foregoing analyses it is seen that the amount of tar and carbon in the soot from domestic fires is much higher than that from boiler furnaces, while in the case of ash, the reverse is true. Domestic soot is thus by far the more objectionable and is produced in greater quantities from the same amount of coal. The amount of acid depends more upon the amount of sulphur in the coal than upon any other single factor, and is given off with the products of combustion whether smoke is produced or not. When, however, soot is produced, a large percentage of the acid is occluded in the soot,

where it is more injurious than if allowed to escape alone into the air. The soot coming in contact with metal, stone and decorations is made to adhere firmly by means of its tar content, in reality covering the surface with a coat of black paint. The acid is not readily washed away by the rain, but continues to act until it is all used up. This acid, absorbed from the air by the rain-water, would be more injurious if it did not drain from most surfaces before its action is completed.

Deterioration of Buildings and Building Materials

After considering the various phases of the chemical composition, one can readily understand why houses in a smoky atmosphere look grimy and miserable; and also why the use of skylights is, in many places, made impossible, while, in others, it is necessary to so arrange them that they may be readily cleaned. Without frequent cleaning such skylights would soon become useless because of the accumulation of soot. Again, changes in design to make a different arrangement of drain pipes, are, at times, necessary in order to prevent the splashing upon the building of rain-water containing soot.

Effect on Building Materials

In a smoky city, too, much more glazed tile and vitrified brick are used for the outside of buildings, as it makes the cleaning a comparatively simple matter — washing alone being necessary. Building stones, such as limestone, marbles or sandstones with calcareous binding material, are rapidly disintegrated by the acid in the soot and air. Therefore, materials such as granite, sandstone (with a silicious binding), and brick, which are not attacked by the sulphurous and sulphuric acids in the soot, should be utilized. But, unfortunately, that stone which is most easily affected, disintegrated by the atmospheric acid and decolourized by soot, is the one which is easiest to work into the desired shape for building purposes. Granite and similar stones, which are practically never attacked by acid and are impervious to moisture, offer little chance for the soot to lodge. They are readily cleaned, but are extremely expensive because of the difficulty in working them. Thus the architect finds himself confronted with financial as well as æsthetic considerations. Stone may be cleaned but, at most, that is but a temporary expedient and represents a periodical tax on the owner. The logical thing is to make cleaning unnecessary by water-proofing the stone and doing away with the smoke. The sulphuric acid acts on calcium carbonate, (the principal constituent of stones, which is most easily corroded by the acid in the soot), forming calcium sulphate (gypsum) which is more soluble in water

than the calcium carbonate. But, at the same time, the acid causes the stone to undergo a physical change, making it swell and become porous, friable and easily disintegrated; it also roughens polished surfaces, thus rendering them more liable to attack by acid, by moisture and by the weather. Dr. Angus Smith has found mortar to contain as high as 28.33 per cent. of sulphuric acid. This, acting upon the calcium carbonate, would form 48.16 per cent. of calcium sulphate.

The effect of the sulphuric acid on most metals is rather marked, and greater than the action of a like amount of acid in the rain-water or air. It would seem from observations taken in Pittsburgh, that the soot containing acid is made to adhere to the metal by means of its tar content, in which place it acts as the one pole which together with the metal and acid, form an electrolytic couple, making corrosion much more rapid. In the case of iron and aluminium, the oxide and basic sulphate are produced, at least in part, from the sulphate, and the acid is used over and over again. To verify these observations experimentally, duplicate sets of various metals were fastened to two boards. One set was protected from the soot in the air by means of cheese cloth, yet still exposed to the air and rain. The other set was left unprotected. The pieces of metal left unprotected from the soot show a much greater amount of corrosion than those which were protected.

The following figures obtained by Messrs. W. B. Worthington and A. Rattray, showing the corrosive effect of the acids in the air, are of interest. To quote from Cohen: "A number of rails were placed in suitable positions by the side of the line, and weighed at intervals, and the loss of weight recorded. The rails were of the ordinary railway section weighing 86 lbs. per yard. The annual loss of weight from corrosion was as follows:"

CORROSIVE ACTION OF ACIDS IN THE AIR

	Average Annual Loss in Weight in lbs. per yard	No. of years Observations
1. In the centre of the town.....	1.04	17
2. In adjoining place in smoky tunnel ...	1.48	13
3. In a wet place in same tunnel	1.71	8
4. On the sea-coast amongst sand hills ..	0.18	17

Building Decorations and Smoke

In designing both interior and exterior decorations for buildings the smoke question must receive as much consideration from the architect as do the tastes of the owners of the buildings. Interior draperies and paper are soiled much more quickly in a smoky city than elsewhere. If light paper

is used in papering the rooms, it must be cleaned every six months and new paper put on every year to keep it looking even half as well as one would wish. The acid in the soot attacks draperies, rendering them useless in a short time. The extra wear of cleaning also shortens their life markedly.

On interior painting the effect is not as marked because cleaning is done oftener. But the problems of interior decoration, and of keeping the outside of a building clean in smoky places, are exceedingly difficult to solve. The statement has been made by a number of painters that they have done jobs which looked as bad after two or three days' exposure as they did before the painting was done. Soot certainly destroys the æsthetic value of paint very quickly. The time which it takes to accomplish the pollution is, of course, dependent upon the amount of soot in the air, the colour of the paint, and the tar content of the soot. The number of paintings needed to keep the same building as presentable as in a smoke-free city will naturally vary greatly. Cases can be cited where it is necessary to paint three or four times as often as would be required for protective purposes only. In the majority of cases, in smoky cities, the number of paintings required is probably doubled. Sometimes it is necessary to remove the soot and tar and to wash the building before applying the new coat of paint. This washing also removes the paint, often making two coats necessary in place of one for a proper covering. After the wood has received ten or twelve coats it is customary to burn off the paint. This is an additional expense and likewise increases the fire risk. The action of soot on the wearing qualities of the paint also depends on many factors involving the chemical composition of the paint and soot. The soot may be acid, neutral or even slightly alkaline. Places are known where the soot seems to act as a protective coating, while in others it corrodes the painted surface, destroying the gloss and rendering it much more easily weathered. The latter is probably true in those cases where the coal burned contains a lot of sulphur and the soot is consequently quite acid.

Smoke and the Weather.

From a preliminary study of available data and a perusal of the literature concerning the meteorological branch of our work we have arrived at the following conclusions:

(1). That city fogs are more persistent than country fogs, principally because of the increased density due to the smoke which accumulates in them.

(2). In consequence of the fog prevalence, there are fewer hours of sunshine in the city than in the country.

(3). The sunshine is less intense than in the surrounding country, the light of short wave length (the blue light in the spectrum) suffering the greater depletion.

(4). Daylight, which often depends entirely upon diffuse daylight from the sky, is depleted by smoke in greater proportion than direct sunlight.

(5). Minimum temperatures are markedly higher in cities than in the country, in part, of course, because of city heating, but principally because the smoke acts as a blanket to prevent the escape of heat at night.

We find, when using a chemical method for determining the intensity of daylight, that, ten miles from the centre of Pittsburgh, on many days there is two or three times the light as measured by chemical action, that there is in the city proper.

The amount of soot in the air varies betweeen 21 and 430 mg. per 1,000 cubic feet of air, depending upon the direction and strength of the wind. That is, we have twenty times the soot in the air on a dark day that we have on a clear, bright day.

Visibility determinations (the distance one can see) vary greatly from day to day. With the accumulation of more data we hope to trace a relationship between these determinations and the amount of soot in the air.

Determination of Soot-fall

The soot-fall (the amount of soot which falls on a given area in a given period of time) is of interest to us from many view-points. A large number of determinations have been made, and, although they vary greatly in different parts of the city, those made at the same stations remain remarkably constant. The total fall varies between 28.42 and 225.6 tons per square mile per month for the cleanest and dirtiest parts of Pittsburgh, respectively. These figures represent the entire dust fall, which is jet black and is considered here, as elsewhere, to represent the soot-fall. Analyses are, however, being made for tar, organic and inorganic matter.

How Vegetation is Affected by Soot

Trees and shrubs add to the beauty of a city. They are not intended primarily as a source of income. The effect of soot on vegetation may, therefore, be considered more particularly a question of æsthetics. Then, too, as the smoke nuisance is usually

prevalent only in cities of some size, its effect is not felt on the crops in the country districts. Yet it makes its injurious action felt, both directly and indirectly. The smoke clouds limit the available daylight for vegetation in two ways.

(1). By smoke clouds. The amount of sunlight as well as diffuse daylight is not nearly as great in a smoky city as it is normally.

(2). By lessening the absorption of light by leaves. If the amount of light cut off by the deposit of tar upon glass can be considered in any sense as a measure, the tar deposit on the leaf is by far the most important factor in preventing light absorption.

The tarry matter contained in the soot coats the leaves and chokes the stomata. This injury is mechanical. Its destructive action does not, however, stop there. Like all other forms of finely divided carbon, soot has the power of occluding other substances. The tar (containing phenols and other bodies of a similar nature) and acids are all poisonous to plant growth and greatly lower the vitality, the acids in particular limiting the activity of the soil organisms, especially those of nitrification.

Cohen and Ruston find that the relative assimilations of laurel leaves in districts where the air contains different amounts of soot vary from 11.6 to 100. Crops of radishes and lettuce grown in different sections of the town show the possibility of correlation of the known atmospheric impurities with the yield of the crops. Trees automatically keep record of the presence of any inhibiting factor by the narrowing of their annual rings. In one case the cross-section of a tree plainly showed evidences of the building of a smoke-producing factory near at hand.

We find that such flowers as roses and carnations will not thrive within the smoky limits of Pittsburgh, and that, for this reason, many greenhouses have been forced to move beyond this deleterious influence. Furthermore, many trees are injured if not entirely killed by the smoke.

Smoke and Disease.

The effect of smoke on health has always been a much mooted question. At the present time in the city of Pittsburgh, it has assumed a very practical form. The city has appropriated considerable money for a tuberculosis hospital and a dispute has arisen as to its situation. Some contend that it should be placed outside the city limits, while others hold that more intensive work can be done if it is erected in that part of the city where the disease is most prevalent. The advocates of the first situation, as part of their

argument, assert that the smoky atmosphere is detrimental to those suffering from the disease, or, at least, that it retards their recovery. The weight of opinion seems to be against this view.

Dr. William Charles White, in a paper read before the Fifteenth Congress of Hygiene and Demography said:

> "As a result of our clinical study we have come to the conclusion that the general death rate from tuberculosis in Pittsburgh is low, that there is nothing in the smoke content of the air which in any way stimulates the onset of tubercular process or militates against the rapidity of recovery from tuberculosis when once this disease has been contracted."

Effect of Smoke on Pneumonia

Dr. White's studies along this line, however, led him to declare, that, from his study of the air content of Pittsburgh as a factor in the causation of disease, that smoke has an important bearing on the pneumonia death rate. Dr. White is in favour of a popular crusade for the prevention of pneumonia similar to that which has been waged against tuberculosis. Of course, in such a campaign serious attention would be given to the smoke problem.

Dr. Louis Ascher of Konigsburg, who has made an extensive study of the effect of smoke and dust on disease, maintains that, in Germany, a smoky atmosphere is responsible for the increased mortality from lung diseases other than tuberculosis. He holds that not only is this increase taking place, but that persons who are the subjects of pulmonary tuberculosis die in smoke-laden districts more rapidly than those persons similarly affected, but living elsewhere. Of the fact that carbon makes its way into the lungs of those who live in a smoky city, there is no doubt. Dr. Klotz has found large amounts of it in the lungs of Pittsburghers, as the following statement indicates:

10.6	grams	in	the	lungs	of	a	man	28	years of age.
3.4	"	"	"	"	"		37	"	" "
2.4	"	"	"	"	"		39	"	" "
4.2	"	"	"	"		woman	37	"	" "
2.6	"	"	"	"	"		44	"	" "

According to Lehmann, while the sulphur dioxide contained in the soot is absorbed by the nasal mucous membrane, the particles of carbon are carried further into the respiratory passages. Finally reaching the lungs, they are deposited there, having, meanwhile, in their descent, given up to the bronchial mucous membrane and the lining membrane of the lungs some of the acids they retained.

Dr. Holman finds that soot acts as a disinfectant. Water seems to dissolve the disinfecting agents in the soot making them more active than when dry. Carbon floating in the, air seldom, if ever, carries bacteria, unless it has lodged on the ground and is again blown into the air. Soot acts as a very effective blanket, protecting bacteria and giving them a chance to grow.

Pittsburgh Sore Throat

Dr. Day finds that diseases of the nose and throat are not appreciably more prevalent in smoky cities, but that they are more severe and harder to cure. This is probably due to the cracking of the mucous membrane by the dry atmosphere in the houses, and subsequent irritation by dust, quite as much as to the action of the smoke. Singers, on visiting Pittsburgh, usually get Pittsburgh sore throat, which lasts about seven days, when they become acclimated for the time being. Unfortunately though, the same thing occurs on each succeeding visit to the city.

The Cost of Smoke.

We are coming more and more to look at the smoke problem as fundamentally an economic one. We have been told time and again that smoke and soot are the products of imperfect combustion which means a waste of fuel, and, consequently, unnecessary expense. But there is more than this to the question: smoke is not only a tax to the producer of it, but it causes a loss to every man, woman and child in the community.

Economic Loss Due to Smoke

Many estimates of varying degrees of accuracy have been made of the financial damage due to smoke and soot. In 1905, the Hon. F. A. Rollo Russell estimated the damage in London to be $26,000,000. The largest single item of this amount was $10,750,000 for extra washing and wear and tear of linens. The Cleveland Chamber of Commerce in 1909 placed the loss for that city at $12 per capita or $6,000,000 for the entire population. Matthew Nelson, Chief Smoke Inspector of Cincinnati, asserted that the loss there was $100 per family. Mr. Paul Bird, in his report as Chief Smoke Inspector of Chicago, declared that the loss in Chicago was at least $17,600,000, or $8 per capita. In a paper read before the American Civic Association, Herbert M. Wilson, Chief Engineer of the United States Bureau of Mines, stated that a careful government inquiry into the toll paid by the people of the United States showed a total of over $500,000,000 or a toll of $17 a year for every man, woman and child in the larger cities.

These figures are startling. It is the task of those who are engaged in the economic phase of the smoke investigation to make the estimates for Pittsburgh as accurate as possible by inquiring into the various items that go to make up the total. They are attempting to deal not in sweeping generalizations, but in what Mr. Wood, in speaking of the work of the Pittsburgh survey, termed, "piled-up actualities."

Cost of Cleaning Buildings

About twenty-five per cent of the cleaning expense of office buildings in the city of Pittsburgh is necessary because of smoke. When it is realized that the cleaning bill of some of the office buildings is $75,000 per year, some conception of the magnitude of expense may be formed. To cite a single item: It costs the owners of a certain building in Pittsburgh $320 more a month for window cleaning than if the building were situated in New York or Philadelphia. The lighting bills in office buildings are increased by half, because of the conditions of the atmosphere in Pittsburgh.

Damage to Goods by Smoke

The damage to goods in wholesale, retail and department stores runs up into the thousands, amounting in the case of one store to as much as $30,000 a year. We have found that it costs from 33 per cent to 50 per cent more to conduct a hospital in Pittsburgh than in other cities. For instance, in the matter of extra cleaning force, one hospital could save $3,000 a year, and another $1,200 if the city were cleaner. In large industrial cities many buildings are washed down or painted once or twice a year. To one firm in Pittsburgh this means an extra expenditure of $700 and in the case of another firm, of $500.

Laundry Expense in Pittsburgh

Census reports on laundries show that the people of Pittsburgh pay more for laundry work than those of almost any other city and that it costs the laundrymen more to do the work. These figures, when compared with the report of smoky days in various cities, seem to indicate that atmospheric conditions, and not custom, determines, in a large measure, the per capita amount of laundry business done.

The laundry schedules of men who now live in Pittsburgh, but who come from other cities, show that they pay from one-third to a half more in Pittsburgh than they paid formerly. They wear at least two more shirts and two more collars per week, which means an extra expense, at the lowest, of $16 each year. The laundry schedules of women who have lived in other cities, show that they each pay $24 more a year in Pittsburgh than elsewhere. The toll paid to steam laundries alone amounts to something like $800,000.

The extra expense in labour, time and effort in home laundry work is much greater than that of steam laundries. As a minimum estimate, Pittsburgh pays a toll of $1,500,000 in laundry and home washing bills.

Dry cleaning is found necessary far more frequently in Pittsburgh than in other cities owing to the atmospheric conditions. Because of this, too, a greater supply of clothing is required, and clothes wear out sooner. Moreover, Pittsburghers are limited in the selection of colours of clothing. Especially is this true of woollen goods, furs, hats and trimmings. The average annual bill of a man in Pittsburgh who sends his clothes to a dry cleaner is $18; a woman's bill is about $20. This is one-half more than the man or woman would pay in a cleaner city. The total extra cost of dry cleaning in the city of Pittsburgh is about $750,000.

Property Values and the Smoke Nuisance

In October, 1912, as a result of the appeal of the property owners in the 24th and 44th wards of that city, who declared that recent sales in their vicinity were at prices far below the assessed valuation because of the smoke nuisance, the Philadelphia assessors reduced the assessed valuation of each from $500 to $2,000 on some three hundred properties. A preliminary survey of conditions in Pittsburgh showed that a similar state of affairs existed there. In some sections, there has been a depreciation of fully 50 per cent in sale prices. Such property is near mills or railroads or, as is often the case, near both. Houses in such neighbourhoods are very difficult to rent, and, in order to rent at all, there must be a reduction in the rental price of at least 20 per cent. Sometimes people rent these houses and move as soon as they become acquainted with the nuisance.

To all these losses—and there are many others—must be added the cost of the fuel wasted through imperfect combustion. In 1881, when a little less than 3,000,000 tons of coal were being used in Pittsburgh, William Metcalf, an eminent engineer and mill-owner, estimated the cost of the coal that was wasted, by poor combustion in mill and factory furnaces, at $1,063,000. At the present time, Pittsburgh burns in the neighbourhood of 15,000,000 tons of coal annually, the cost of which is about $19,000,000. It has been estimated, on the basis of efficiency tests, that 21 per cent of this goes up the chimney in the form of smoke.

The Problem of Abatement.

The problem of the abatement of smoke presents many and various phases. In the method of attack, in the different cities, there are a number of factors which must be taken into consideration.

(1). The topography of the country is an important factor in the mitigation of the evil. A hilly country, such as that in which Pittsburgh is situated, confines the smoke to the valleys, so that it is not readily carried away by the wind as it is in Chicago and other cities built on a flat country.

(2). The situation of the smoke-producing plants with reference to the residence district must be taken into consideration. In many places, this proves a source of great annoyance; in others, it tends to simplify the problem. In Pittsburgh, the mills are situated along the Ohio, Allegheny and Monongahela rivers, which run through the city, bounding at least three sides of the best residential districts. Recalling the topography of the city, one can see that this does not facilitate abatement.

(3). The necessity for burning soft coal in private dwellings is a great bane, the methods for burning it without smoke not being nearly as well perfected as in the case of large installations. About six per cent of the coal burned in fire-places and other domestic installations escapes through the chimney as soot, while only about 0.5 per cent of that burned in power plants is thus wasted. That is, weight for weight, the coal burned in domestic installations is twelve times more a nuisance than that burned in a hotter furnace under a boiler. Cities which have at their disposal a supply of natural or other cheap gas, are greatly favoured.

(4). Cities, such as Philadelphia, which have access to cheap hard coal, should have very little need of consideration in connection with the smoke problem. Anthracite coal is a smokeless coal. On the other hand, soft coals vary greatly in the ease with which they are burned without smoke. Different types of mechanical stokers and other kinds of installations are required in many cases. Each district presents new engineering problems. An installation which gives perfect satisfaction with one kind of fuel will not of necessity do so with another.

(5). Smoke abatement is not a difficult task in non-manufacturing towns, where power-plants are the exception rather than the rule. In manufacturing towns, on the other hand, long continued campaigns of education are necessary before even the enforcement of an ordinance is possible.

After a thorough perusal of literature on smoke and a general survey of the smoke-producing plants in the Pittsburgh district, a number of facts were firmly established:

(1). That the production of smoke was in most cases unnecessary and could be prevented with economy to the power-plant operator.

(2). No thoroughly practical method is known for abating the smoke in round-houses, coke ovens, and one or two special furnaces.

(3). No matter how perfect a smoke-preventing device has been installed, without intelligent operation, it will not be of much value for the prevention of smoke; that is to say, the fireman must be educated to do his work in a proper manner.

(4). Public opinion viewed the smoke nuisance as implying industry and prosperity for the city.

(5). No investigation of the subject as a whole has been made by the co-ordinated efforts of a group of men.

We find that certain types of installation are notorious 'smokers' while others are practically free from smoke at all times.

Furnace	No. of Stacks Observed	No. Violating the City Ordinance
Type 1	45	26
" 2	21	3
" 3	8	0
" 4	23	15
" 5	15	0
" 6	1	0

The human element must not, however, be neglected in this connection. It is possible for a skilled fireman to operate a hand-fired furnace without objectionable smoke, even if it is not correctly constructed. But, given an unskilled or careless man in charge, the most modern of plants may become the most objectionable smokers in the neighbourhood.

To do away with smoke and thus increase efficiency, one must bear in mind three things:

(1). The mechanical contrivance for burning the coal must be suited to the purpose.

(2). The fireman must be trained to do his work in a proper manner.

(3). Some method of furnace control should be employed—CO_2 recorders and pyrometers—so that the efficiency of the furnace and the amount of smoke produced may be known both to the fireman and the superintendent.

THE RAILWAY LOCOMOTIVE CREATES A SMOKE NUISANCE IN CITIES.

ADDING TO THE PALL OF SMOKE OVER PITTSBURGH

Rivers run through the main portion of the city and the steamboats add their quota of smoke to the murky atmosphere.

The Question of Legal Regulation

As legislation follows rather slowly, the agitation for, and need of certain reform measures and, as the question of smoke abatement in the United States is of comparatively recent date, there need be no surprise to find that the passage of ordinances on the subject, especially of ordinances that are in any way effective, has taken place only in the last ten years. This is not true, however, of England, where the law took cognizance of the smoke nuisance as early as 1273, when the use of coal was prohibited in London as prejudicial to public health. There is in existence a statement that one John Doe was in 1306, tried, condemned and executed for burning coal in the city of London. Since 1273 there have been numberless proclamations, parliamentary commissions, laws and ordinances on the smoke nuisance.

Anti-Smoke Legislation in U. S.

It was about thirty years ago that cities of the United States began to pass smoke ordinances. However, as early as 1856 an ordinance was introduced in the council of Cleveland to prohibit the use of soft coal in manufacturing plants, and sometime prior to 1869, Pittsburgh passed an ordinance which contained the provision "that no bituminous coal or wood should be used in the engine of any locomotive employed in conducting trains upon any railroad." Chicago and Cincinnati were the first cities to pass general ordinances on the subject, the first ordinance in Chicago being passed in 1881. Pittsburgh did not have an ordinance until 1891, and then it applied only to a section of the city.

At the present time all cities having over 200,000 population—with the exception of a few cities in which the problem is not acute---have smoke ordinances. Many of the smaller cities which are far-sighted enough to be on their guard have enacted anti-smoke laws.

The popular conception of the police power is to consider it as extending only to the protection of life and property in its narrow sense, and the maintenance of public order. But more and more it is becoming apparent that its great sphere is public health, and general welfare. This police power may be delegated by the state legislature to municipal corporations and this is the power under which municipalities declare certain acts nuisances. While a municipality may be authorized in general terms to declare what shall constitute a nuisance, it may not declare that to be a nuisance which in fact is not. In common law 'dense' smoke is not a nuisance *per se* though some courts have held it to be so in a populous city.

The Pittsburgh ordinance of 1906 was held void for two reasons, one of which was "that the legislature of Pennsylvania had likely not given the city sufficient authority to pass an ordinance upon the subject." The city at once sought and secured the power. Thus, it can be seen that, in order to deal with the smoke nuisance, cities are required to seek specific authority from the state legislature. When a municipality is thus empowered it is then in position to pass an ordinance.

Requirements of a Smoke Ordinance

It is a difficult matter to say what the essential provisions of a smoke ordinance should be, and yet, from the experience of the different cities, it is possible to point out certain features that are necessary if the ordinance is to accomplish any notable results.

It is becoming characteristic of the age to count on preventive rather than remedial legislation for telling achievement. This thought leads us to one of the fundamental functions of a smoke ordinance, that it should make provision for prevention, so far as possible, of the installation of improperly designed furnace equipment. For this purpose, the ordinance should provide that plans and specifications for all construction work on furnaces be submitted to the smoke inspector, and be approved by him before the work is started. This feature leads us to the point that, since it is so important a provision, the ordinance should state the qualifications of the man whose duty it is to pass on these plans and specifications. Surely it should provide that he be an engineer, "qualified by technical training and experience in the theory and practice of the construction and operation of steam boilers and furnaces."

An ordinance, of course, should state the density of smoke that is to be permitted, and provide a standard of measurement. On the first point, care should be taken lest the provision be somewhat vague, for this has been the rock upon which many ordinances have been wrecked in court. In speaking of this feature—the fixing of the density—Mr. S. B. Flagg of the United States Bureau of Mines, says: "The requirements should represent the best practice, the standard set should not be an impossible nor an impracticable one, neither should it represent ordinary or poor practice." In some ordinances, a stack well within the limits set by the ordinance may be responsible for the discharge of many times as much soot as another stack which violates the ordinance. Such an ordinance is obviously incongruous.

The mere enactment of a reasonable, efficient and enforceable smoke ordinance is not enough. The ordinance must be enforced.

At this point most of the cities have fallen short. Sometimes the wrong methods are used in the enforcement of the ordinance, most of the time the methods employed are altogether too lax and feeble to secure even mediocre results. To remedy this situation there is one great weapon—public opinion. However, in order to educate, concentrate and focus public opinion, a league or union of civic and commercial organizations should be formed in each city. Such organizations seem imperative in American cities until better results are secured by way of enforcing smoke ordinances. Eternal vigilance on the part of the public is the price of a smokeless atmosphere, but to those who enjoy such a blessing this effort brings ample returns.

Enough has been said to suggest that the smoke nuisance is an economic question and that the people who are most concerned are not those who make the smoke but those who suffer because it is made. It is necessary, therefore, to educate the public as to the evils of the nuisance, so that an active and intelligent public opinion may be brought to bear on those who are responsible for it. As has been pointed out, even with the smoke makers, this problem is an economic one. The abolition of the smoke nuisance, therefore, unlike many other social nuisances against which outcry has been made, would result in direct and immediate gain both to the public at large and to those who are chiefly responsible for the nuisance itself.